Preplanned Studies

Association Between Refractive Status and Ocular Biometric Parameters Among Children and Adolescents — 10 PLADs, China, 2020–2024

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Summary

What is Already Known About This Topic?

Myopia prevalence among Chinese students remains persistently high, with axial length and the axial length-to-corneal radius ratio demonstrating significant associations with refractive status in children and adolescents.

What Is Added by This Report?

This investigation employed cycloplegic optometry to assess refractive errors across children and adolescents in 10 provincial-level administrative divisions, utilizing axial length (AL) and axial length-to-corneal radius ratio (AL/CR) as predictive indicators of refractive status.

What Are The Implications For Public Health Practice?

The AL/CR ratio demonstrates superior predictive accuracy for myopia compared to AL alone and can effectively identify at-risk children during early developmental stages. Incorporating routine monitoring of AL and AL/CR into school health programs can enhance early detection capabilities and support targeted myopia management strategies.

ABSTRACT

Introduction: Myopia prevalence among Chinese children and adolescents remains persistently high, with an alarming trend toward earlier onset. Understanding the correlation between ocular biometric parameters and myopia development provides essential insights into underlying mechanisms. This study evaluated the associations between axial length (AL), axial length-to-corneal radius ratio (AL/CR), and spherical equivalent refraction (SER) across different age groups to inform early detection strategies and myopia management protocols.

Methods: Students aged 5–18 years were recruited from 10 provincial-level administrative divisions across China between November 2020 and July 2024 using hierarchical clustering and probability proportionate to size (PPS) sampling methods. The final analytical sample comprised 60,270 participants. Trained professionals conducted cycloplegic optometry and measured ocular biometric parameters. Data underwent weighted analysis using nonparametric tests and receiver operating characteristic (ROC) curve analysis to establish predictive thresholds for myopia detection.

Results: Overall myopia prevalence reached 29.24%, demonstrating a progressive increase across school grades. Median SER values exhibited increasingly negative trends with advancing educational levels. Correlation analysis revealed that AL/CR demonstrated stronger associations with SER (R=–0.750, P<0.001) compared to AL alone (R=–0.657, P<0.001). ROC analysis confirmed superior predictive accuracy for AL/CR over AL across all age groups, with area under the curve values approaching or exceeding 0.88 among upper-grade students.

Conclusions: Both AL/CR and AL serve as effective indicators for identifying children at elevated myopia risk during early childhood. Routine monitoring of AL and AL/CR within school health programs can facilitate early intervention strategies and myopia control measures, particularly in regions with limited access to cycloplegic optometry services.

In 2018, China elevated myopia prevention and control to a national strategic priority; however, myopia prevalence among Chinese children and adolescents has remained persistently high, with overall rates reaching 52.7% by 2020 (*1*) and demonstrating a concerning trend toward younger age of onset. Axial myopia represents the predominant form of myopia in Chinese youth (*2*), and accumulating evidence indicates that the axial length-to-corneal radius ratio

(AL/CR) correlates more strongly with refractive status than axial length (AL) alone (*3*–*5*). Investigating the relationships between ocular biometric parameters and myopia development provides fundamental insights into myopia pathogenesis. Compared to automated refractometers that measure only refractive error, biometric parameter assessment offers the distinct advantage of identifying high-risk populations earlier, enabling early intervention before visual acuity deteriorates. Although previous studies have examined correlations between ocular biometric parameters and myopia in Chinese students, most have focused on specific regions, with national-scale investigations remaining limited. Therefore, leveraging the comprehensive monitoring system for hyperopic reserves among children and adolescents established across 10 provincial-leveladministrative divisions (PLADs) in China beginning in 2020, this study examined AL, corneal radius (CR), and AL/CR in students from these ten regions. We analyzed the distribution of refractive parameters and their associations with refractive status to further elucidate ocular growth patterns and refractive development in students, while evaluating the monitoring effectiveness of ocular biometric parameters for refractive development to inform myopia prevention and control strategies.

The National Disease Control and Prevention Administration of China coordinated a cross-sectional survey of hyperopic reserves across 10 PLADs from November 2020 to July 2024. These included Liaoning Province, Beijing Municipality, Zhejiang Province, Guangdong Province, Henan Province, Hunan Province, Shanxi Province, Shaanxi Province, Shandong Province, and Chongqing Municipality. Students from senior kindergarten through high school were selected using multistage cluster sampling at each site. Initially, 67,260 participants were surveyed. Exclusions included 22 individuals with diseases affecting visual development or interfering with ophthalmic examinations, 6,030 with missing spherical equivalent data or abnormal post-mydriasis values, 171 outside the 5–18 year age range, and 767 with missing or abnormal right eye AL or corneal radius (CR) values. The final sample comprised 60,270 participants: 14,475 kindergarten students, 28,482 lower-grade primary school students (grades 1–3), 11,317 upper-grade primary school students (grades 4–6), 3,496 junior high school students, and 2,500 senior high school students. All participants provided informed consent, and the study received institutional ethics committee approval (batch number: 2022 [24]). Myopia was defined as spherical equivalent refraction (SER) ≤–0.50 D in either eye under cycloplegia (*6*). Classifications included non-myopia (SER>–0.50 D), mild myopia (–3.00 D≤SER≤–0.50 D), and moderate myopia (–6.00 D≤SER<–3.00 D). Cycloplegic refraction employed 0.5% compound tropicamide eye drops administered four times at 5-minute intervals, with refraction performed 30 minutes after the final instillation. Intraocular pressure measurement was conducted when clinically indicated. All regions selected ocular biometric measurement instruments based on local resources, with standardized equipment brands and models used whenever possible.

Statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Since SER, AL, and AL/CR did not follow normal distributions, we reported data as median values with interquartile ranges and used non-parametric tests for comparisons. The Mann–Whitney U test was employed for two-group comparisons, while the Kruskal–Wallis test was used for multiple-group analyses. Correlations between variables were assessed using Spearman's rank correlation coefficient. To determine optimal cut-off points for AL and AL/CR in predicting myopia onset, we calculated the Youden index and constructed receiver operating characteristic (ROC) curves with corresponding areas under the curve and 95% confidence intervals. When Youden indices were equivalent, we prioritized sensitivity over specificity. Statistical significance was established at $P<0.05$.

This study examined the visual status of 60,270 students aged 5–18 years across 10 PLADs in China, comprising 31,070 boys and 29,200 girls. The overall myopia prevalence was 29.24%. Myopia prevalence among kindergarten, lower-grade primary school, upper-grade primary school, junior high school, and senior high school students was 5.20%, 19.76%, 56.49%, 79.12%, and 83.28%, respectively. Student myopia prevalence demonstrated a significant increasing trend with advancing grade levels (χ^2=15,989.103, $P<0.001$), with statistically significant differences between each grade after Bonferroni adjustment. The overall myopia prevalence was lower in boys (28.04%) than in girls (30.51%) (Table 1).

Correlation analysis demonstrated that SER values between left and right eyes, as well as biometric parameters between eyes, exhibited strong correlations ($R>0.9$). Consequently, only right eye data were

TABLE 1. Myopia prevalence among students by gender and grade level (%).

Grade	Male	Female	Total
Kindergarten	5.50	4.85	5.20
Lower grades of primary school	19.64	19.88	19.76
Upper grades of primary school	52.80	60.55	56.49
Junior high school	76.02	82.08	79.12
Senior high school	80.66	85.91	83.28
Total	28.04	30.51	29.24

included in subsequent analyses. The median SER values [M (Q25, Q75)] for kindergarten, lower-grade primary school, upper-grade primary school, junior high school, and senior high school students were 1.00 (0.63, 1.38) D, 0.63 (0.00, 1.00) D, −0.50 (−1.88, 0.38) D, −1.88 (−3.38, −0.38) D, and −2.38 (−3.75, −0.75) D, respectively. SER values progressively decreased with advancing grade levels, with statistically significant differences between all grade comparisons (P<0.001). Median AL values [M (Q25, Q75)] across grade levels were 22.56 (22.06, 23.02) mm, 23.00 (22.46, 23.53) mm, 23.81 (23.16, 24.45) mm, 24.34 (23.67, 25.01) mm, and 24.59 (23.82, 25.36) mm, respectively. AL demonstrated a consistent increase with grade progression, with significant differences between all grade levels (P<0.001). Corneal radius (CR) values [M (Q25, Q75)] remained relatively stable across grades: 7.77 (7.60, 7.94) mm, 7.77 (7.60, 7.95) mm, 7.79 (7.62, 7.96) mm, 7.79 (7.61, 7.97) mm, and 7.80 (7.64, 7.98) mm. The AL/CR ratio [M (Q25, Q75)] increased progressively across grade levels: 2.90 (2.86, 2.95), 2.95 (2.90, 3.01), 3.05 (2.98, 3.13), 3.13 (3.04, 3.21), and 3.15 (3.06, 3.24), with significant differences between all grade comparisons (P<0.001) (Table 2).

Female students consistently demonstrated SER values equal to or lower than their male counterparts across all grade levels. Male students exhibited greater AL and CR measurements compared to females in all grades. The AL/CR ratio was higher in male students across all grades except senior high school, with all differences reaching statistical significance (P<0.05) (Table 2).

Spearman correlation analysis revealed strong associations between ocular biometric parameters and refractive status. AL demonstrated a high negative correlation with SER (R=−0.657, P<0.001), while AL/CR showed an even stronger negative correlation (R=−0.750, P<0.001). Regardless of the student's refractive classification, the correlation between AL/CR and SER consistently exceeded that observed between AL, CR, and SER (Table 3).

ROC curve analysis established optimal cut-off values for myopia prediction across all school grades. For AL, the cut-off points were 23.10 mm (kindergarten), 23.24 mm (lower-grade primary school), 23.72 mm (upper-grade primary school), 24.00 mm (junior high school), and 24.12 mm (senior high school). The corresponding areas under the ROC curve were 0.724 (95% *CI*: 0.704, 0.744), 0.784 (95% *CI*: 0.777, 0.791), 0.801 (95% *CI*: 0.793, 0.809), 0.824 (95% *CI*: 0.809, 0.840), and 0.858 (95% *CI*: 0.840, 0.876), respectively. For AL/CR, the optimal cut-off values were 2.97 (kindergarten), 2.99 (lower-grade primary school), 3.04 (upper-grade primary school), 3.07 (junior high school), and 3.10 (senior high school). The AL/CR parameter demonstrated superior predictive accuracy with areas under the ROC curve of 0.825 (95% *CI*: 0.808, 0.843), 0.854 (95% *CI*: 0.848, 0.860), 0.881 (95% *CI*: 0.875, 0.887), 0.885 (95% *CI*: 0.872, 0.897), and 0.882 (95% *CI*: 0.865, 0.899) for the respective grade levels.

DISCUSSION

Cycloplegic mydriatic optometry represents the internationally recognized gold standard for myopia diagnosis. This study employed post-mydriasis SER measurements to determine myopia status, ensuring reliable diagnostic accuracy. Additionally, our findings provide comprehensive baseline data on SE, AL, CR, and AL/CR ratios for children aged 5–18 years across 10 Chinese PLADs, addressing the limited availability of ocular biometric parameter data for East Asian pediatric populations.

Research demonstrates that the AL/CR ratio may serve as the optimal myopia indicator (*7*–*8*). Our analysis confirmed that AL/CR exhibited stronger correlations with SER compared to AL alone across all refractive error categories. Consequently, we employed the Youden index to establish optimal sensitivity-specificity combinations for AL and AL/CR myopia

TABLE 2. Effects of grade level and sex on spherical equivalent refraction and ocular biometric parameters among children [M (Q25, Q75)].

Parameter	Kindergarten	Lower grades of primary school	Upper grades of primary school	Junior high school	Senior high school	H	*P*
SER (D)							
Total	1.00 (0.63, 1.38)	0.63 (0.00, 1.00)	−0.50 (−1.88, 0.38)	−1.88 (−3.38, −0.38)	−2.38 (−3.75, −0.75)	18,308.070	<0.001*
Male	1.00 (0.50, 1.38)	0.63 (0.00, 1.00)	−0.38 (−1.75, 0.50)	−1.75 (−3.25, −0.25)	−2.00 (−3.63, −0.50)	8,529.575	<0.001*
Female	1.00 (0.63, 1.50)	0.63 (0.00, 1.13)	−0.63 (−2.00, 0.38)	−2.00 (−3.38, −0.59)	−2.50 (−3.88, −1.00)	9,789.880	<0.001*
Z	−9.131	−3.899	−6.967	−3.265	−4.104		
P	<0.001*	0.002*	<0.001*	0.001*	0.001*		
AL (mm)							
Total	22.56 (22.06, 23.02)	23.00 (22.46, 23.53)	23.81 (23.16, 24.45)	24.34 (23.67, 25.01)	24.59 (23.82, 25.36)	17,839.505	<0.001*
Male	22.83 (22.37, 23.25)	23.22 (22.76, 23.76)	24.00 (23.38, 24.67)	24.60 (23.97, 25.32)	24.78 (23.98, 25.57)	9,170.277	<0.001*
Female	22.25 (21.86, 22.70)	22.72 (22.22, 23.22)	23.60 (22.98, 24.20)	24.08 (23.44, 24.81)	24.40 (23.69, 25.06)	9,842.362	<0.001*
Z	−46.824	−54.150	−22.987	−14.139	−7.929		
P	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*		
CR (mm)							
Total	7.77 (7.60, 7.94)	7.77 (7.60, 7.95)	7.79 (7.62, 7.96)	7.79 (7.61, 7.97)	7.80 (7.64, 7.98)	81.673	<0.001*
Male	7.83 (7.67, 8.00)	7.84 (7.67, 8.01)	7.85 (7.68, 8.03)	7.85 (7.68, 8.03)	7.84 (7.69, 8.02)	22.471	0.009*
Female	7.69 (7.54, 7.87)	7.71 (7.55, 7.88)	7.73 (7.58, 7.90)	7.73 (7.55, 7.91)	7.76 (7.58, 7.92)	86.936	<0.001*
Z	−30.661	−40.687	−23.493	−13.521	−9.884		
P	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*		
AL/CR							
Total	2.90 (2.86, 2.95)	2.95 (2.90, 3.01)	3.05 (2.98, 3.13)	3.13 (3.04, 3.21)	3.15 (3.06, 3.24)	20,161.492	<0.001*
Male	2.91 (2.87, 2.96)	2.96 (2.91, 3.02)	3.05 (2.98, 3.14)	3.14 (3.04, 3.23)	3.15 (3.06, 3.25)	10,026.251	<0.001*
Female	2.89 (2.85, 2.93)	2.94 (2.89, 3.00)	3.04 (2.97, 3.13)	3.12 (3.04, 3.20)	3.15 (3.07, 3.24)	10,273.051	<0.001*
Z	−18.051	−18.548	−4.942	−3.660	−0.840		
P	<0.001*	<0.001*	<0.001*	0.001*	0.401		

Note: M represents the median, Q25 represents the 25th percentile, Q75 represents the 75th percentile, H represents the Kruskal–Wallis test statistic for ocular biometric parameters across different school grades, and Z represents the Mann–Whitney U test statistic for comparing ocular biometric parameters between sexes within each grade.
Abbreviation: SER=spherical equivalent refraction; AL=axial length; CR=corneal radius; AL/CR=axial length-to-corneal radius ratio.
* *P*<0.05 indicates statistically significant differences.

TABLE 3. Correlation analysis between spherical equivalent refraction and ocular biometric parameters across different refractive status groups [M (Q25, Q75)].

Group	SER (D)	AL		CR		AL/CR	
		R	*P*	*R*	*P*	R	*P*
Non−myopia	0.75 (0.38, 1.25)	−0.42	<0.001*	−0.004	0.358	−0.531	<0.001*
Mild myopia	−1.38 (−2.00, −0.88)	−0.414	<0.001*	−0.001	0.882	−0.546	<0.001*
Moderate myopia	−4.00 (−4.63, −3.50)	−0.299	<0.001*	0.008	0.630	−0.424	<0.001*
Total	0.50 (−0.50, 1.00)	−0.657	<0.001*	−0.001	0.001*	−0.750	<0.001*

Note: Data are presented as medians with 25th and 75th percentiles (Q25 and Q75).
Abbreviation: SER=spherical equivalent refraction; AL=axial length; CR=corneal radius; AL/CR=axial length-to-corneal radius ratio.
* *P*<0.05 indicates statistical significance.

prediction thresholds. Both AL and AL/CR demonstrated robust predictive accuracy across all grade levels, with ROC curve areas exceeding 0.7. However, AL/CR consistently outperformed AL in myopia prediction across every grade level, as evidenced by larger ROC curve areas. These findings suggest that when AL or AL/CR values — particularly AL/CR — exceed corresponding grade-specific

thresholds, clinical vigilance is warranted.

This research's primary strength lies in its large-scale population survey encompassing ten Chinese PLADs, utilizing post-cycloplegia spherical equivalent refractive error as the diagnostic foundation. Compared to previous studies employing non-cycloplegic refraction results, our approach provides a more accurate pediatric vision status assessment. However, several limitations warrant consideration. The cross-sectional design permits statistical association identification but precludes causal inference establishment. Furthermore, the ocular biometric parameter thresholds derived from this study enable current myopia status prediction rather than future myopia development forecasting.

In conclusion, myopia prevalence among children and adolescents in East Asia remains consistently elevated, with China demonstrating particularly concerning rates. Both AL and AL/CR exhibit strong correlations with myopia development, establishing them as valuable indicators for myopia detection. Screening protocols utilizing established AL and AL/CR threshold values represent a non-invasive, rapid, and accurate public health strategy that enables early myopia detection and population-based prevention, effectively reducing both incidence and severity.

Conflicts of interest: No conflicts of interest.

Ethical statements: Received ethics approval from the institutional review board of Beijing Centers for Disease Prevention and Control (2022 No.24).

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